

Atmospheric Control of the Surface Energy Budget

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LONG-TERM GOAL

Understand how the atmosphere/ice system responds to changes in large-scale atmospheric forcing, including weather events, the seasonal cycle, and recent and historical decadal trends.

OBJECTIVES

(1) Document the recent increased strength in the Arctic atmospheric polar vortex, termed the Arctic Oscillation (AO). Special emphasis is on spatial co-variability. The AO is associated with increased wind speeds at middle altitudes (~ 500 mb), lower surface pressures, warmer temperatures at lower altitudes and colder stratospheric temperatures. The AO includes all of the Arctic region and was not generally manifest before 1970. It is seen in the early 1970s and is especially strong in the 1990s. (2) Document how such large-scale atmospheric changes influence regional sea ice thermodynamic and dynamic processes based on the heterogeneous and plastic nature of sea ice. Sea ice is far from homogeneous on scales of 1-300 km. Major kinematic features are concentrated in long, narrow slip lines. In winter, surface fluxes are upward over thin ice and downward over thick ice.

APPROACH

We make use of basin scale gridded data sets of atmospheric and sea ice variables, AVHRR data, SAR ice motion vectors, and in situ ice thermodynamic and kinematic observations. The basin scale observations include analysis fields at all levels of the atmosphere and satellite estimates of the surface radiation budget and ice concentrations. AVHRR thermal imagery and SAR ice kinematic data provides the regional context for more limited in situ ice motion, stress and surface flux data collected during the SHEBA experiment. Investigation of the gridded sets uses four-dimensional pattern recognition, both statistical and observational, based on dynamic principals. A key issue is how northward heat fluxes vary geographically in different weather regimes. Regional ice studies interpret ice kinematic features in terms of ice rheology theory, based on the plastic nature of sea ice.

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WORK COMPLETED

An array of six drifting buoys were placed in the vicinity of the SHEBA ice camp in fall 1997 with data telemetry via satellite. Five stations reported through spring 1998 and four stations reported through summer 1998. An inner array of 3 buoys had global positioning system (GPS) to accurately determine relative ice motions. Two locations provided 10-month records of long and short-wave radiation. The radiation sensors were mounted in a special opening/closing container to reduce frosting. To our knowledge these are the first long-term automated radiation measurements in the Arctic.

One sea ice dynamics manuscript was revised and two atmospheric manuscripts were written.

RESULTS

We have shown an increasing connection between Arctic atmospheric circulation and that at lower latitudes. While the AO has spun up the polar vortex in the central Arctic, weather systems in N.E. Asia/N. Pacific are weaker, particularly in the 1990s.

We have also shown that sea ice behaves as plates ($\sim 40 \times 200 \text{ km}^2$) separated by narrow sliplines when the Beaufort ice pack is forced by strong, sustained winds. The sliplines tend to line up at acute angles between themselves and with the wind direction. This behavior is similar to a granular material such as wet sand, where the separation between sliplines is much greater than the grain size. This granular behavior can be modeled mathematically as a hardening plastic.

IMPACT/APPLICATIONS

Our results add more credibility to the conjecture that Arctic atmosphere and ice conditions have changed in the 1990s compared to the 1980s and before. Whether this change is part of interdecadal variability or a long-term trend is unknown. To separate cycles from trends, more work needs to be done on the mechanisms which sustain the positive AO circulation to separate cycles from trends. Our results on sea ice as a granular material provides credibility to next generation sea ice models such as PIPs3. The basic mathematical formulations of sea ice models from the late 1970s are correct; what is needed is to solve these equations with a fine enough numerical resolution ($\sim 5\text{-}10 \text{ km}$).

TRANSITIONS

The successful deployment of the radiometers is a milestone for the Arctic community and has implications for future integrated observing systems.

The SAR/buoy analysis was the basis for interpretations of in situ stress data from SIMI and SHEBA.

PUBLICATIONS

Overland, J.E., S.L. McNutt, S. Saolo, J. Groves and S. Li. 1998: Arctic sea ice as a granular plastic, *Journal of Geophysical Research* 103, 21845-21868.

Overland, J.E. J.M. Adams, and N.A. Bond, 1999: Decadal variability of the Aleutian low and its relation to high latitude circulation, *Journal of Climate*, in press.